Retina and Choroid Imaging with Transcranial Back-illumination

Timothy D. Weber[1,*] and Jerome Mertz[1,2]

[1] *Department of Biomedical Engineering, Boston University, 44 Cummington Mall, Boston, MA, 02215, USA*
[2] *Boston University Photonics Center, 8 St. Mary's St., Boston, MA, 02215, USA*

[*] *Corresponding author: tweber@bu.edu*

Abstract: We present an alternative illumination scheme for retinal imaging. It is based on near-infrared light delivered transcranially at the temple and light diffusion towards the retina. This unique transmission geometry simplifies absorption measurements and enables clear imaging as deep as the choroid. © 2018 The Author(s)

OCIS codes: (170.4460) Ophthalmic optics and devices; (170.2945) Illumination design; (170.1470) Blood or tissue constituent monitoring.

1. Introduction

Ophthalmoscopy and fundus photography are standard clinical methods for examining and documenting the human retina [1]. Both methods focus light through the subject's pupil and capture widefield images of the light reflected from the retina. The key innovation is that the strong corneal back-reflections, which normally prohibit view of the back of the eye, are avoided by spatially segmenting the illumination and reflection beam paths.

While these techniques provide excellent visualization of superficial retinal features, they struggle to provide as clear a picture of deep structures such as the retinal pigment epithelium (RPE) and choroid, both of which are strongly implicated in common ocular diseases such as age-related macular degeneration (AMD) [2]. Similar to how corneal back-reflections limit direct imaging of the retina, visualizing these deep structures is again challenged by back-reflections—except in this case, the back-reflections are caused by horizontally-aligned cell layers in the inner retina itself. The contributed noise from these spurious back-reflections easily dominate the relatively weak reflection signatures from deep structures.

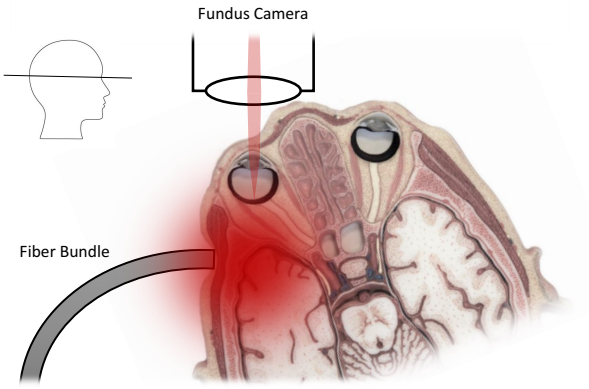

Fig. 1. Transverse slice through the human head showing the concept of transcranial back-illumination of the retina.

2. Transcranial Back-illumination of the Retina

To address this challenge, we propose an alternative illumination strategy based on near-infrared (NIR) light delivered transcranially through the subject's temple. As depicted in Fig. 1, the light diffuses through the bone and illuminates the retina not from the front, as with conventional methods, but rather mostly from the back. As such, we image

light transmitted through the retina rather than reflected from the retina. Our transcranial back-illumination system is inspired by the success of oblique back-illumination microscopy (OBM) for imaging thick tissues in a transmission geometry [3] and functional near-infrared spectroscopy (fNIRS) which remotely probes cortical blood oxygenation dynamics through intact skull. [4]

2.1. Proof of Principle System

The proof of principle system is based on a commercial non-mydriatic fundus camera (Topcon TRC-NW5S). The fundus camera's built-in illumination system is disabled and replaced with transcranial NIR illumination from a high-power LED source (λ = 850nm, Thorlabs M850L3). To avoid exposing the subject to excessive heat generated at the LED, the light is coupled into one end of a fiber bundle (∅1/2", Edmund Optics 39-370), the other side of which is pressed against the subject's temple. The fundus camera is equipped with a CCD camera (PCO Pixelfly USB), operated in IR-boost mode and allowed to free-run.

3. Preliminary Results

A series of f MATLAB software ar (Fig. 2b). Since the a ge by first local-maxi image by the high-S for a filter radius of 6

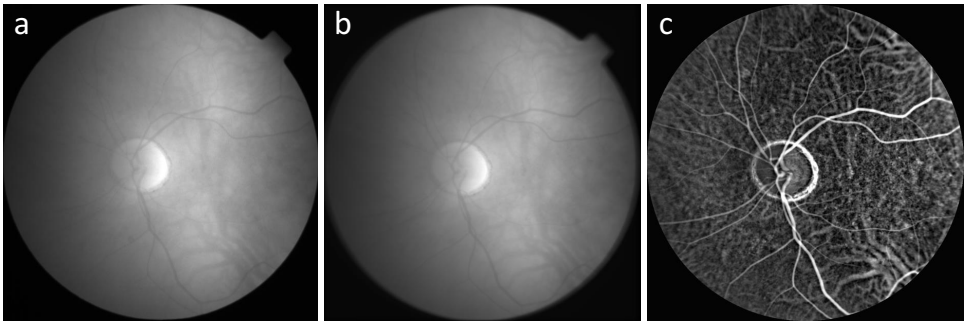

Fig. 2. Retinal back illumination examples (λ = 850nm). Several raw frames (a) are registered and averaged to form a high-SNR frame (b), and processed to estimate relative absorption (c).

4. Anticipated Results

In the past, elaborate models have been required to quantitatively interpret reflection-mode retinal images [5]. The transmission geometry proposed here may simplify pathlength considerations for absorption spectroscopy and lead to improved oximetry results. To test this hypothesis, we plan to upgrade the system to include several different, temporally multiplexed LEDs. We also plan to upgrade to an NIR-sensitive, faster CMOS camera.

References

1. M. D. Abramoff, M. K. Garvin, and M. Sonka, "Retinal Imaging and Image Analysis," IEEE Rev. Biomed. Eng. **3**, 169–208 (2010).
2. P. T. V. M. de Jong, "Age-Related Macular Degeneration," N. Engl. J. Med. **355**, 1474–1485 (2006).
3. T. N. Ford, K. K. Chu, and J. Mertz, "Phase-gradient microscopy in thick tissue with oblique back-illumination," Nat. Methods **9**, 1195–1197 (2012).
4. G. Strangman, D. A. Boas, and J. P. Sutton "Non-invasive neuroimaging using near-infrared light," Biol. Psychiatry **52**, 679–693 (2002).
5. T. T. J. M. Berendschot, P. J. DeLint, and D. van Norren, "Fundus reflectance–historical and present ideas," Prog. Retin. Eye Res. **22**, 171–200 (2003).